The Late Edwin H. Armstrong

The tragic death of the principal creator of modern radio occasions this brief review of the trials and tribulations and achievements of an independent inventor in the U. S.

by Lawrence P. Lessing

When Edwin Howard Armstrong jumped from a 13th-floor window of River House in New York City on February 1, there died one of the authentic innovators of our time. He had conceived the three basic circuits upon which rests the whole of modern radio communications. The first is the regenerative feedback circuit (1912) which took wireless telegraphy out of the spark-gap, crystal-detector stage into continuously amplified sound; the second is the superheterodyne (1918), which underlies all modern radio and radar reception; the third is wide-band frequency modulation or FM (1933), a novel system of high-frequency broadcasting which excludes noise and is the core of developments in high-fidelity sound.

Though Armstrong received many professional honors and large financial rewards, he was not the stereotype of a great American inventor. He was born in New York City in 1890, the son of John Armstrong, who was for many years U. S. representative of the Oxford University Press. In this comfortable, bookish household, later removed to a big house in Yonkers, young Armstrong was soon absorbing the stories of Watt, Volta, Hertz, Tesla and Marconi, devouring the works of Michael Faraday, who remained his lifelong idol, and rigging wireless contraptions in the attic like other young "hams" of the day. At Columbia University, to which he commuted from 1909 to 1913 on a red Indian motorcycle, he entered electrical engineering and came under the inspiring teacher Michael Pupin. From his early teens he had shown an urge to go beyond textbooks into the unknown. He made his first great invention while still a junior at Columbia; his second while still in his twenties, serving as an Army Signal Corps Major in France. At the war's end he returned to Columbia to teach, experiment and eventually take over Pupin's chair, a position which, with its precious freedom to investigate, he never relinquished.

Armstrong's early inventions, vital to the lusty new radio industry, brought him almost immediate wealth. In 1912 his father had refused him $150 with which to file a patent application on his feedback circuit, asking him to wait until he was graduated. In 1913, when he filed the patent, he would cheerfully have sold it for $10,000 and a job. None of the big communications companies made an offer. Right after the war, however, the Westinghouse Electric & Manufacturing Company offered him $530,000 over 10 years for both his regenerative and superheterodyne patents, and he sold them. (Later the government forced the radio industry to pool all electronic patents, and the right to license them for radio uses was centered in the new Radio Corporation of America.) In 1922 Armstrong sold a lesser invention, the super-regenerative circuit, to R.C.A. for $200,000 and 60,000 shares of R.C.A. stock, which was later raised to 80,000 shares for consulting services, making him the largest individual stockholder in the corporation.

Armstrong, then 32, went to Europe, lived expensively and brought back a Hispano-Suiza to indulge his love for fast cars and to dazzle R.C.A. President David Sarnoff's secretary, Marian MacInnis, whom he was courting. One windy night, to impress her, he impulsively climbed to the top of the 400-foot transmitter tower of the new radio station WJZ in 42nd Street. Armstrong and Miss MacInnis were married in 1923, and on their honeymoon to Palm Beach he carried the first portable radio, built for the occasion.

Despite behavior that suggests an F. Scott Fitzgerald novel, Armstrong remained a serious professor of electrical engineering, with more than a touch of worldly shrewdness (he sold most of his R.C.A. stock at a peak price of $114 a share before the 1929 crash). He was of the same breed as the Wright brothers: practical, thorough, soundly trained, tenacious in defense of his ideas and his rights. If he was less successful in establishing his claims to fame, this may have been due partly to the fact that he was never his own best advocate and that while the Wrights' achievements were soon visible in large, shining vehicles riding the skies, Armstrong's were as invisible as the radio waves carrying a song. His major accomplishments were contained within the vacuum tube.

In 1939, when I first met Armstrong, he was at the height of his long battle to establish FM. In 1935 he had demonstrated FM before the Institute of Radio Engineers and in months of successful tests in R.C.A.'s facilities atop the Empire State Building. Getting no action from the industry and finding himself stalled by the Federal Communications Commission on a license to erect an experimental FM station of his own, he threatened to take it to a foreign country. In 1937 he was allowed to build a full-scale FM station, in which he invested $300,000, at Alpine, N. J. In the next two years he gave demonstrations of FM's superior radio quality to all who would listen.

The demonstration I attended started with a briefing in his Columbia laboratory, from whose walls two portraits of Faraday looked sternly down; afterward Armstrong drove us first to Alpine and then far out on Long Island to the house

of a friend who had an FM receiver. When the set was turned on, the Alpine program came in out of a blank silence, as if there were no receiver at all. Armstrong telephoned an assistant at Alpine: "Suppose we have a few tricks first, John." A match was struck, a glass of water poured, a gong tapped, and all were reproduced on Long Island with utmost faithfulness. Then a pianist began a Mozart sonata, and there issued from the black box such full, natural tones as had never been heard. FM broadcasts were repeatedly recorded at this location with the same steady, limpid clarity through thunderstorms and other atmospherics that make ordinary radio an affront to the ear more than half the time.

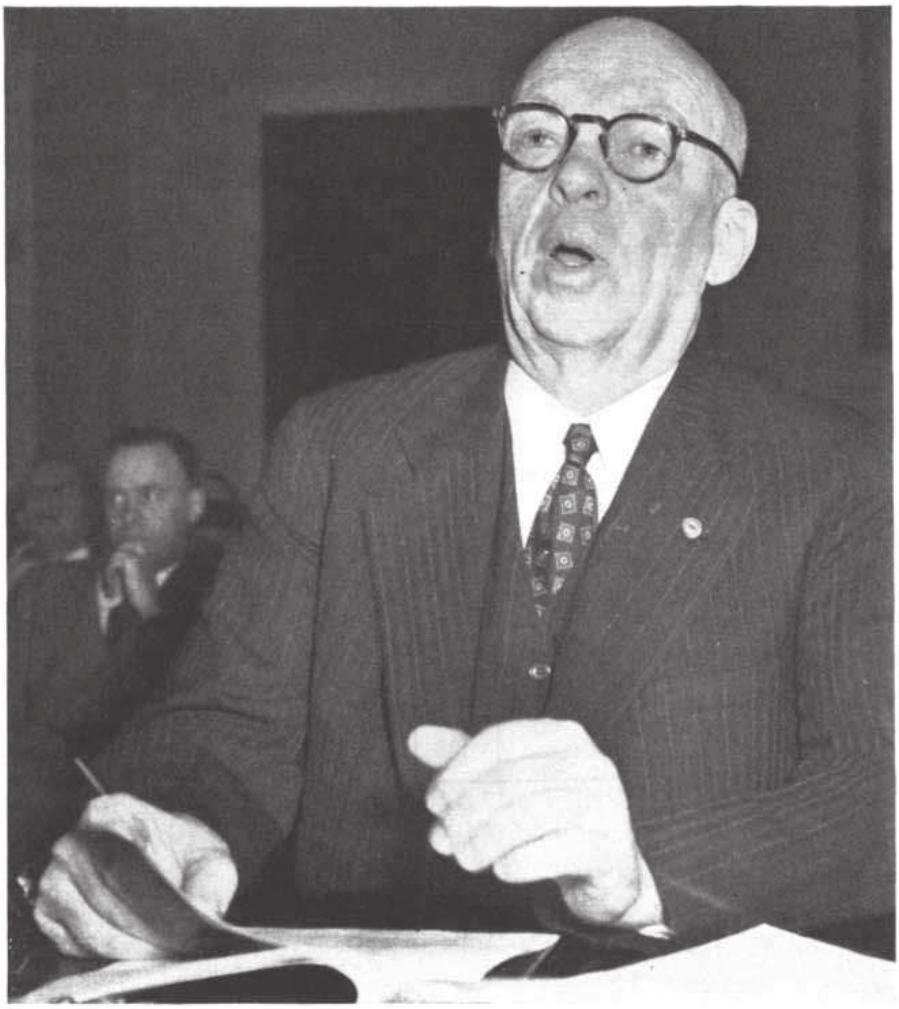
Short-wave FM was not merely a tonal advance but a different broadcasting system. It made possible many more radio stations and networks than could ever be crowded into the limited long-wave radio bands. The inventor offered the FM patents only for licensing, not for sale. He was determined to administer FM himself in order to control its quality. Regular radio, to his sensitive ear, had had its technical standards steadily lowered by the overcrowding of stations in limited frequencies and by a flood of inferior receivers. Naively, he was shocked by the stony silence and opposition with which most of the radio industry greeted FM. The industry coldly informed him that the public was not interested in high fidelity, and moreover, with television just on the horizon, that FM had come too late. Armstrong never forgave this rebuff.

Like his model Faraday, whose discoveries founded the electrical industry, Armstrong was an original, non-mathematical thinker in electromagnetic waves. He shied at equations, not because he was ignorant of mathematics but because he preferred to think first in physical terms of particles, currents, frequencies, circuits, then to reduce his observations to mathematics. Too many discoveries had been put off by figures which said they were impossible. His forte was the sharp analysis of ambiguous physical phenomena. He was never so happy as when flying in the face of some accepted theory or confounding an unimaginative engineer. His deepest reverence was for "the laws of nature." Though his discoveries were not as basic as Faraday's, they went far beyond narrow invention.

This is well illustrated in his working out of the regenerative circuit. In 1883 Thomas Edison observed a mysterious effect. Experimenting with a plate inserted in an incandescent lamp, he noticed that when he connected the plate to the positive terminal of a battery, a current leaped across the space between the lamp's hot filament and the plate. Edison passed over the phenomenon as insignificant. It took until 1904 for an English physicist, Sir John Fleming, to puzzle out the "Edison effect" and put it to use in the Fleming valve—the first electronic tube. It had two elements: a filament and a plate. Two years later, in the U. S., Lee De Forest added a third element—a metal grid between the filament and the plate which could control or modulate the current across the space by small voltage changes on the grid. He thereby created essentially the electronic vacuum tube of today.

Its possibilities for radio were not realized at the time. Again a tiny effect was observed, which De Forest passed over and failed to explain. When the tube was tuned to a certain frequency in a circuit, it emitted a faint, long-drawn whistle. In 1911 young Armstrong found the answer. Like a dozen more eminent investigators he was searching for a means of amplifying wireless signals, which were then too weak for effective transoceanic communication. Testing and analyzing the tube's performance, Armstrong came to the startling discovery that, properly hooked up, it was a powerful amplifier. The whistle De Forest had heard had been the tube imperfectly amplifying. When the tube's electrical output was purposefully fed back on the input line to the grid in an endless loop, it multiplied weak incoming signals hundreds of times. When, later, Armstrong allowed it to amplify beyond a certain value, the tube began sending out its own oscillating, high-frequency radio waves. In 1914 Armstrong wrote two historic papers fully delineating the regenerative feedback principle and plotting the first curve—now an engineering commonplace—showing how the vacuum tube really worked.

His next two inventions, which came in short order, were of the more striking "accidental" sort. He was led to the

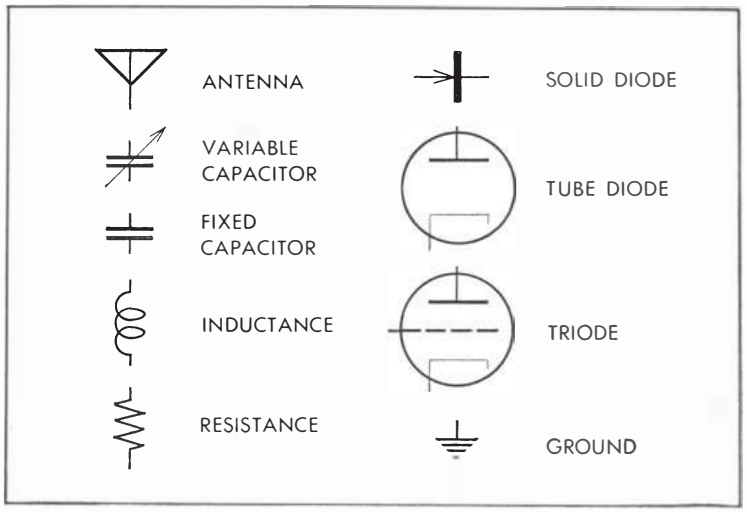


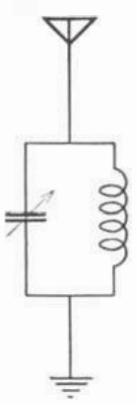
ARMSTRONG was born on December 18, 1890, and died on February 1 of this year. This photograph was made in 1948 as he testified before a Congressional committee on FM.

superheterodyne by a mathematical dispute over a circuit called the heterodyne. He solved the problem by experimental means, and its solution, plus two chance observations on unrelated military problems, suggested a circuit which would overcome feedback limitations and give thousandfold amplification. The next invention was pure chance. While resetting his regenerative apparatus to prove that a patent lawyer had garbled a law of nature, he suddenly pulled in an amazingly loud signal. This proved after some days of analysis to be super-regeneration, now used in special military and police systems. "Ninety-nine out of 100 experimenters," said his coworker Alan Hazeltine on presenting him with the Edison Medal of the American Institute of Electrical Engineers in 1942, "would have failed either to notice the effect or to find its cause."

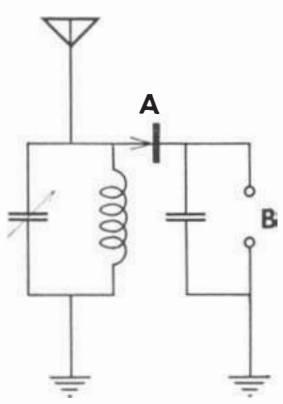
FM came at the end of a dogged, 20-year search in which Armstrong had chased many will-o'-the-wisps. Static in radio is essentially the same electrical phenomenon as the radio signal itself: *i.e.*, amplitude-modulated waves of varying power. Hence it is extremely difficult to keep static out of AM radio, even with heavy power and ingenious filters. Searching for a way around this impasse, Armstrong about 1925 found a way to transmit signals by varying not the power but the frequency of the waves. Many experimenters had tried this and pronounced it unworkable for radio use. But all had attempted to employ FM like AM radio, transmitting it on as narrow a band of frequencies as possible for sharp tuning. Armstrong conceived the idea of allowing the frequencies to swing over a wide band. This not only made FM workable but allowed for the full frequency range of the human voice and music. The band width required put FM up into the more spacious, relatively un-

The wiring diagrams below depict in simplified form the evolution of

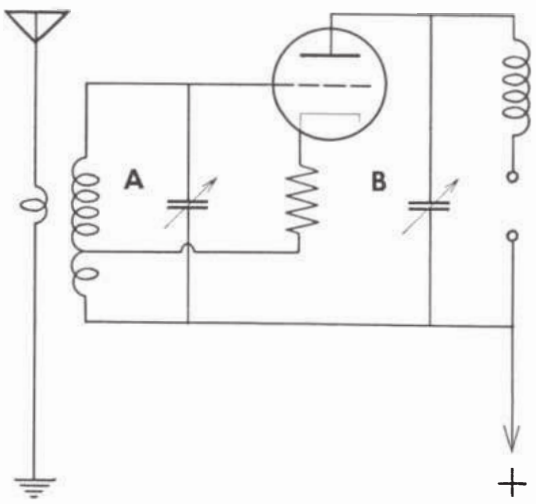




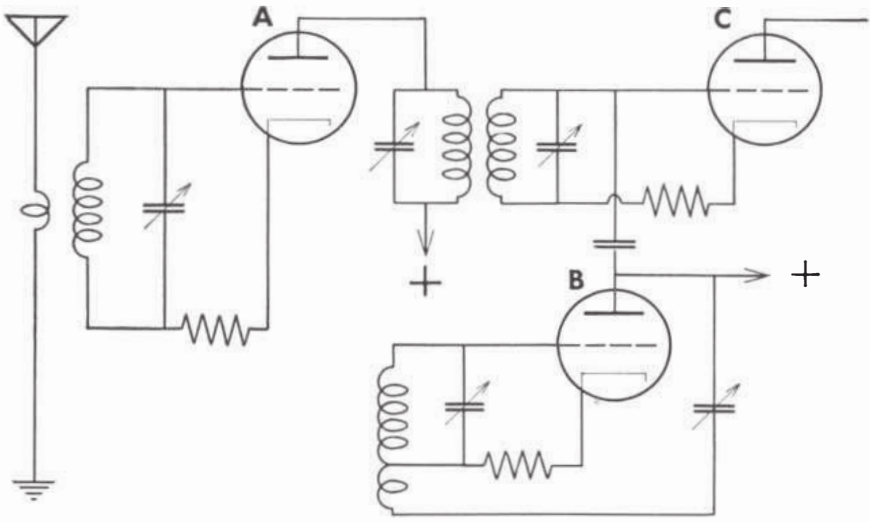
TUNED CIRCUIT is resonant to frequency of an incoming signal.



CRYSTAL (A) detects signal, *i.e.*, changes it to direct current for the output (B).



SUPER-REGENERATIVE CIRCUIT amplifies radio signal so much in circuit A that the tube begins to oscillate. The oscillation is quenched by circuit B.



SUPERHETERODYNE CIRCUIT is quieter and more selective of frequencies than the super-regenerative. Incoming signal is amplified in circuit A. Circuit B generates oscillations of a frequency differing from that of the in-

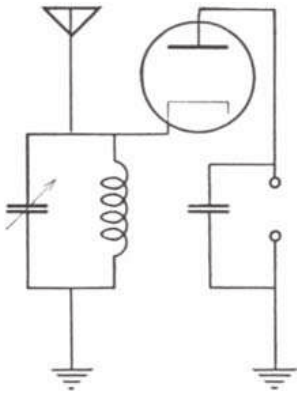
tenanted ultrashort waves, where there is less static to deal with.

In essence Armstrong's solution was to employ a type of electromagnetic wave not normally found in nature. Generated by a specially designed transmitter and sent to a special receiver, it forms a closed system into which normal static cannot break. Since the signal's amplitude is held constant, FM can operate on a small fraction of the power of AM radio with a clarity unmatched by the most powerful clear-channel stations. Its range, however, is limited to not much farther than the horizon.

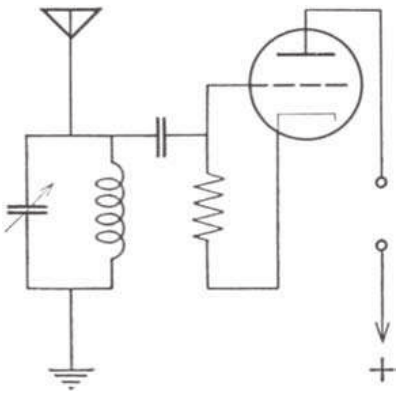
Most of Armstrong's life work was done in the arena where the patent and research departments of great corporations contend for advantage. He had an early baptism of litigation. In 1914, shortly after Armstrong filed his feedback patents, De Forest applied for patents on a similar system called the "Ultraudion" circuit. Armstrong received his patents in 1914, De Forest in 1924. For 12 years a violent battle was fought in the courts. The radio industry first backed Armstrong's patents, which it owned, then switched to De Forest's, which it also owned but which had an additional 10 years to run. Armstrong carried the case alone up to the Supreme Court, seeking vindication. The Court, following the technical facts with difficulty, found for De Forest. Shaken and emotionally distraught, Armstrong returned to the I.R.E. a citation and medal it had awarded him in 1917. The organization refused to take it back. In 1941 and 1942 two technical juries, after again reviewing the case, awarded Armstrong the Franklin medal and the A.I.E.E. top medal for his three major inventions.

FM was to give Armstrong an even worse legal headache. In 1940 the Federal Communications Commission awarded to FM radio the frequency band it had previously given to experi-

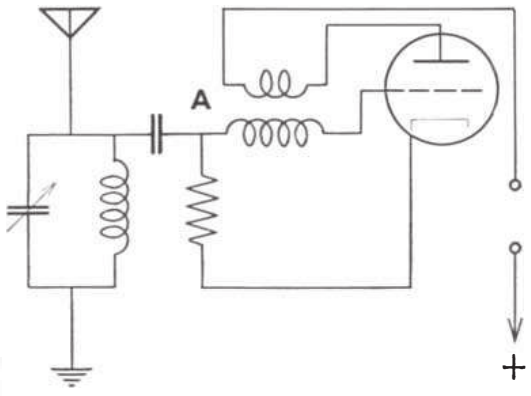
radio from the crystal detector to wide-band frequency modulation



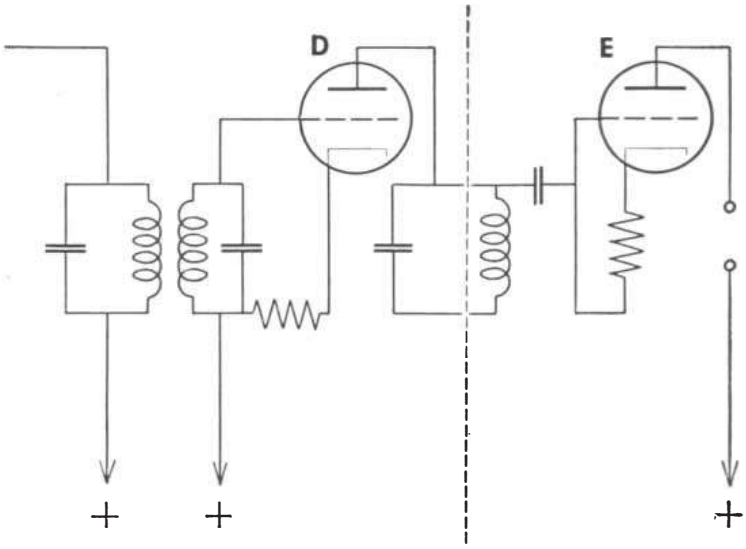
TUBE DIODE has the same function as crystal diode. Neither device amplifies the radio signal.



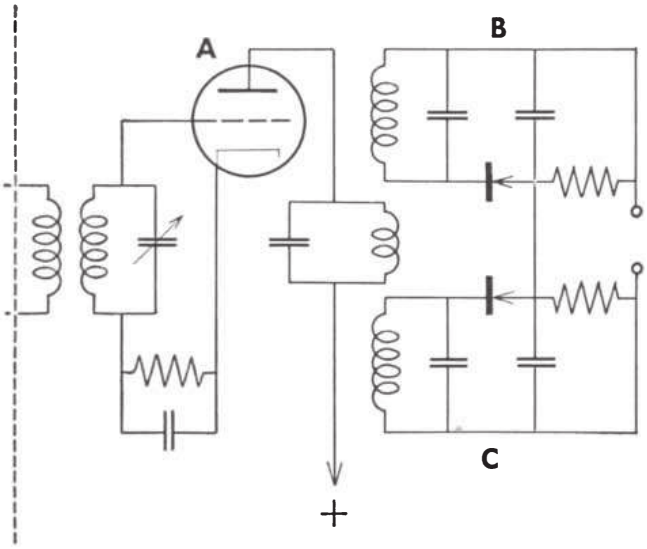
TUBE TRIODE adds grid to diode, modulates large local current in pattern of radio signal. It amplifies signal about 100 times.



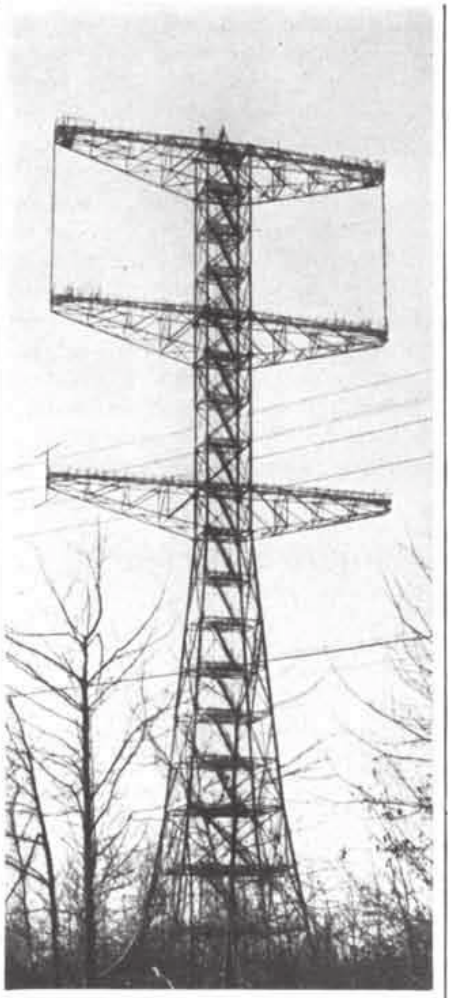
REGENERATIVE CIRCUIT feeds some of the amplified current back through the grid by means of coils (A). It amplifies signal about 1,000 times.



coming signal. The two frequencies are mixed in circuit C. The resulting beat frequency (the difference between the two frequencies) is amplified in circuit D. It is finally detected in circuit E.



WIDE-BAND FM CIRCUIT is the same up to the dotted line. Circuit A limits amplitude of signal. Circuit B is tuned to higher frequencies; circuit C, to lower. Their output is mixed.



TOWER and radio station were built by Armstrong at Alpine, N. J., to work with FM.

mental television, moving the latter to a higher frequency. In addition, it ordered all of television's audio circuits to be changed to FM, as they are now. Soon 40 FM stations and 500,000 sets were operating. The large AM networks added FM facilities.

After World War II (during which FM served in most of the mobile short-range military communications) the F.C.C. dealt FM broadcasting two severe blows. It moved the broadcasting to higher bands, making all transmitters and sets obsolete, and, on an AM network suggestion, it drastically cut the allowable station power in order to limit each station to a "single market" area. This hurt small networks of independent FM stations, which had been relaying programs by air from one station to another. Nevertheless, by 1949 there were more than 600 FM stations on the air, and high-fidelity radio has now become a $300-million-a-year business.

Throughout all this, only a few manufacturers paid Armstrong royalties on his FM patents. Most set-makers used a type of FM (the "ratio detector"), first heard of in 1946, which Armstrong charged

was merely a cut-rate, inferior version of his invention. He brought suit. The suit has dragged on in pre-trial hearings for five years.

Bitterest of all to Armstrong was the fact that FM showed no signs, as he and others had predicted, of supplanting AM radio. The AM networks merely duplicated their AM programs on FM, developed few if any live programs for FM standards and failed to develop independent advertising revenue from FM outlets. Small, independent FM stations, isolated in single markets, had rough sledding economically and, therefore, artistically, and many went out of business. Armstrong himself anonymously put up some $1,200 a month for high-fidelity toll lines between Washington and Boston to hold the old FM Continental Network together for such programs as the Library of Congress' chamber music series. He also kept his old Alpine station going. This station operated for 16 years at a cost of more than $1 million. Last month, after his death, it was shut down.

Armstrong's life was a mixture of great achievement and of nagging adversities which finally killed him. Perhaps he might have been happier if he had followed Faraday's example of renouncing the financial exploitation and rewards of his discoveries. Yet if he had not pressed FM, it might still be only a document in the Patent Office. He, like Marconi toward the end of a busy life, looked longingly and prophetically at the microwaves, in which he was certain there were discoveries yet to be made, but his trials did not give him time.

At the end he was weary of the battle. I talked with him late last December. His basic FM patent was running out. His suit showed every sign of outlasting the De Forest action. He would not be consoled by the slowly growing popularity of FM and the high-fidelity idea. He had placed great hope in a new F.C.C., but that was gone. He had a sense of failure such as often creeps in upon the best and most creative minds.

In his big, lonely apartment overlooking the East River Armstrong wrote a last letter to his wife (who had gone off to Connecticut because he refused to retire and relax). His funeral in the Fifth Avenue Presbyterian Church was attended by his Columbia University associates, some of the world's leading electronic engineers and the captains of the radio industry he had founded. "Greatness," said Ralph Waldo Emerson, "is a property for which no man gets credit too soon."